ELECTRICAL ENERGY FOR A MODERN HOTEL

BY
G. R. MEADE
G. C. ERICKSON

ARMOUR INSTITUTE OF TECHNOLOGY

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Electrical energy for a
modern hotel

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ELECTRICAL ENERGY FOR A MODERN HOTEL

A THESIS

PRESENTED BY

G. R. Meade
G. C. Erickson

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

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Approved
E. H. Freeman
Prof. of Elect. Eng.

L. C. Monin.
Dean of Cult. Studies

H. M. Raymond
Dean of Eng. Studies

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M46

Electrical Energy for a Modern Hotel.

In it the aim of the writers of this thesis to determine whether it is more economical for a modern hotel to purchase the necessary electrical energy for its operations from the central station, or to install a power plant and generate its own power. As the general conditions of all modern hotels are very similar it is considered necessary only to work out the comparative cost for a typical example and say that the results obtained apply in general to all modern hotels.

In a large hotel where it is necessary to have a large heating plant generally operated at a high pressure only the fixed charges against the cost of additional machinery over and above that required for the heating system can be set against the cost of power. Likewise, during the season when the engine's exhaust can be used in the heating system, only the coal required to produce the heat lost between the boilers and the engine's exhaust can be charged against the production of electrical energy. The salary of additional help required for the care of the engines is the labor bill, and of course only the oil waste, etc., actually used in and around the engines, is chargeable against the electrical plant.

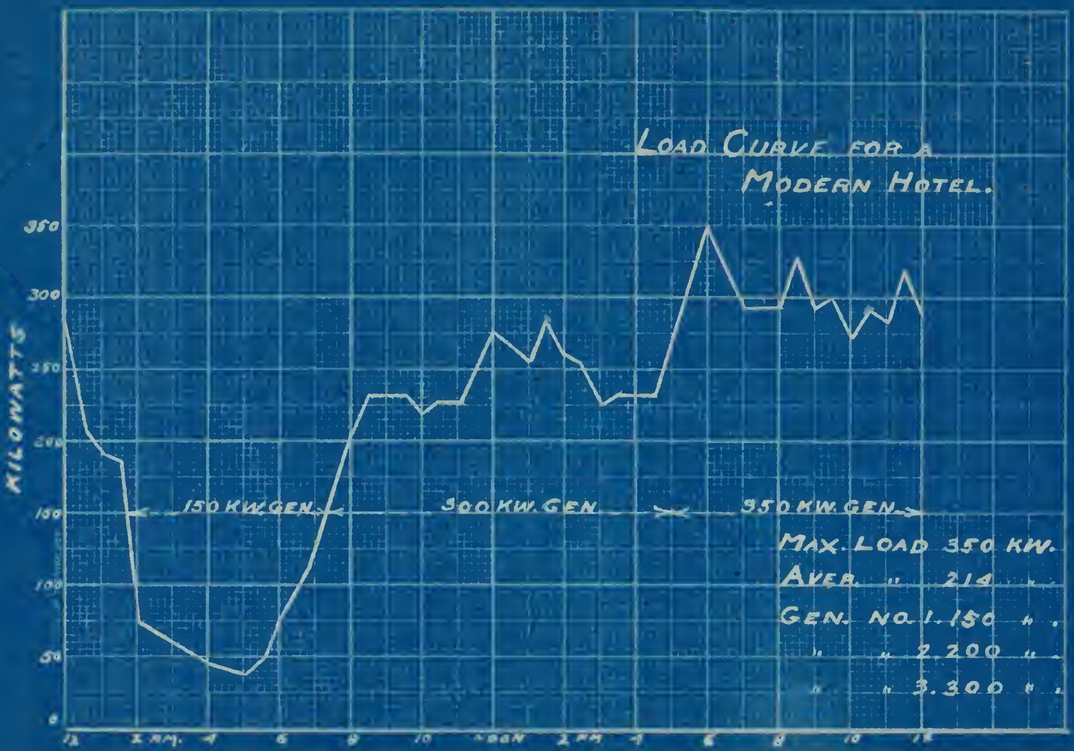
The hotel chosen was the Hotel Sherman, Chicago. At present this hotel is buying power from the Common-

23467

wealth Edison Co., and has no electrical plant of its own. It was thus decided to design a plant for the hotel and to determine the cost of generating energy in connection with the heating system, and compare this with the price paid the Commonwealth Edison Co.

The Hotel Sherman is a thirteen story fireproof building, located at the North West corner of Clark and Randolph Streets, Chicago. There are 757 guest rooms which are heated by direct radiation. The banquet halls and lobbies are heated and cooled by the direct system from fan blasts. Steam is produced at a pressure of 150# gauge. The ice plant is of the ammonia absorption type of seventy five ton capacity, installed by the York Manufacturing Co. The writers, however, laid out a carbon dioxide plant, made up of two, fifty ton units, manufactured by the Kraeshell Ice Machine Co. The latter plant is laid out in part of the space now occupied by the present one, and has been chosen because it takes up less place, requires less attention and is more healthful. The equipment of the kitchen and laundry is of the most modern form, and a large quantity of the plant's steam consumption is charged up against this branch of the hotel.

There are about 16000 fifty watt lamps throughout the building. The motor load amounts to 658 horse


LOAD CURVE FOR A
MODERN HOTEL.
KILOWATTS
350
300
250
200
150
100
50
0
12
2 A.M.
4
6
8
10
NOON
2 P.M.
4
6
8
10
12
150 KW. GEN.
300 KW. GEN.
350 KW. GEN.
MAX. LOAD 350 KW.
AVER. " 214 " .
GEN. NO. 1. 150 " .
" " 2. 200 " .
" " 3. 300 " .

power divided up as follows: laundry 55.6 H.P., bake shop 2.75 H.P., printing room 2 H.P., wine room 2.5 H.P., Yoeman pumps, 9 H.P., coal conveyor 7 H.P., ice plant 10 H.P., kitchen 14.5 H.P., dumb waiters 15 H.P., elevators 200 H.P., and 342 H.P. for the ventilating fans, having a combined capacity of 460,000 cubic feet.

The power plant was designed by the writers from a load curve similar to the present load curve, but about twenty percent in excess of the maximum curve yet obtained. This was done so that any increase in load could be amply taken care of and because of the fact that at present two more floors are being added on to the hotel. This curve shows a maximum consumption of 350 kilowatts, occurring at 6 P.M. The minimum load is 35 kilowatts, and the average load is 214 kilowatts. This gives a load factor of 61.4 percent.

The design calls for four Stirling Boilers, each of 300 horse power rating. Allowing forty pounds of steam per horse power per hour, with feed water at 210° F., three of the boilers will carry the maximum load without being overloaded. Thus at least one boiler is left in reserve at all times. The boilers are to be operated at 150# pressure, and are of the class 5#19 type, having three steam drums, each 42 in. in diameter, and one mud drum 48 in. in diameter. These boilers, including foundations, will be installed for

$5250.00 each. Greenchain grates are to be used, costing $1100.00 each, which cost includes two four horse power engines for the operation of the grates. Three of the above boilers are necessary for the hotel equipment (not including the electrical plant). Thus only one can be charged against the electrical equipment, which would amount to $6350 for boiler and grate, and $19,050 for the hotel plant.

Most pumps are to be in duplex. The feed pumps are to be installed by the Canton Hughes Co. for a cost of $1500.00. They are to be 8 in x 5 in. x 18 in., and furnish water at the rate of 24 gals. per minute, at a speed of 33 feet per minute. This supply is ample for the Hotel plant. For the generator engines the same pumps can be used and run at a speed of 52 ft. per minute, supplying 32 gallons per minute. Thus only the small increase in steam consumption can be charged against the engines. Other pumps include, two pumps for house use, 12 in. x 9 1/4 in. x 8 in.-speed 33 ft. per minute, one fire pump 18 in. x 10 in. x 12 in.- 1000 gallons capacity, and one flood pump; all to be installed by the Canton Hughes Co. at a cost of $3700.00. Two steam pumps for the heating system, 10 in.x 14 in. x 20 in., and two pressure pumps for temperature regulation are to be installed by the American Pump Co., at a combined

cost of $1715.00. The Yeoman Pump Co. will install one bilge pump, 200 gallons per minute, at a cost of $800.00, including a basin, also two ejector pumps at a cost of $1900.00.

The feed water heater will be installed by the Stewart Heater Co. at a cost of $1500.00, for a boiler capacity of 1200 H.P., a heater for 900 H.P. boiler rating would cost $960.00. Thus $540 must be charged against the electrical plant.

The coal conveyor is to be installed by the Link Belt Co., and of the Peck type. The buckets are to be 24" x 18" x 14" and have a carrying capacity of 1.68 cubic feet. One carrier motor of 7 1/2 H.P. capacity is to give a speed of 40 feet per minute. A grate walk is to be built along upper row of buckets and over the bunkers. The complete cost will be $4,000.00. This bid would be about $3200 for a three boiler installation or $800 must be charged against the electrical plant.

The generators are to be of the following capacity, 1-300 kilo watts, 1-200 kilowatts, 1-150 kilowatts. They are to be three wire, 220 volt, and to be installed by the Cracker Wheeler Co. at a cost of $11,000.00. They are to be direct connected to Ball single cylinder Corliss type engines of cylinder sizes,

20"×32",
-x 18" x 27", and 16" x 20" and run at speeds of 150 R.P.M., 150 R.P.M. and 200 R.P.M. respectively. These engines under 150 lb. pressure have steam consumptions, for all loads, well under 26 lbs. of steam per horse power per hour. Concrete foundations for the engines generators are to be built at a cost of $3400.

The cost of piping can be estimated at $9000 for the plant, as designed, and $6000 for the hotel equipment, including three boilers, pumps, etc. Thus $3000 must be charged against the electrical equipment for piping.

The switch board is to be installed and connected to generators by Kohler Brothers. The board is to be as shown in design and of oil finished Mansan Maine slate. The generator panel equipment will consist of:

Panel for 300 kilowatt generator, 1-500 amperes "LL" Ite circuit breaker, 2-2500 ampere Weston ammeters, 2-1500 amperes - 250 volts, double pole switches,1- 6000 ampere single thrown switch, 1-4 point voltmeter receptacle, mounting of field rheostat.

Panel for 300 kilowatt generator.
1-1000 ampere "L.L" Ite circuit breaker 2-1500 ampere Weston ammeters, 2-1000 ampere,220 volts, double pole switches, 1-500 ampere single pole switch, 1-4 point voltmeter receptacle, mounting for field rheostat.

Panel for 150 kilowatt generator.
1-800 ampere "LL" Ite circuit breaker, 2-1200 ampere Weston ammeters, 2-800 ampere -250 volt double pole switches, 1-400 ampere single pole switch, 1-4 point voltmeter receptacle, mounting for rheostat.

Lead encased, rubber covered, cable installed, in iron conduit is to be used for making all connections between generator panels and generators. Balance coils are to be located on the back of the switchboard. The cost of feeder and generator panels and connections will be $9123.00. The cost of the feeder panels amounts to $4500.00.

Above and in front of each boiler a coal bunker is to be built of reinforced concrete construction and 25 tons capacity, at a cost of about $1500.00 each. This makes a charge of $4500.00 against the hotel plant and $500.00 against two electrical plant. An ash bunker, divided into the compartments with a total capacity of 250 tons is also to be built alongside of the coal bunkers. About the same size ash bunker would be required for either 3 or4boilers and so no direct charge can be made against the electrical plant. The cost of the ash bunker will be $1500.00. The chimney will cost $7000, and breeching $500.00, of which amount $1500 must be set against the cost of generating electrical energy. Connection is made with the Illinois tunnel, through which ashes will be carried and

coal may be brought direct to conveyor.

As previously stated the Ball Corliss type engine will run at all loads, with a steam consumption under 26 pounds steam per horse power per hr. Making allowances for losses in the steam line between the boilers and engines, and generator losses 40 lbs. of steam per kilowatt hour at switchboard is considered a conservative value. The daily electrical output is 214 kilowatt x 24 hours = 5136 kilowatt hours, and amounts to a steam consumption of 40 x 5136 = 205,440 lbs. steam per day.

The average steam consumption for the laundry, kitchen, absorption iceplant, and heating system, is 280,000 lbs. The minimum, or summer consumption for 5 months is 165,000 lbs. steam per day for five months, and the maximum, or winter consumption for 7 months is 36,2,000lbs. steam per day. The difference in the heat of the exhaust and live steam for this type of the engine can be taken at 20% of the entering heat to the engine. This value will include steam consumed in the plant accessories that supply the engines. Thus 205440 x80% = 164352.# of exhaust steam is available for use. The minimum demand of the Hotel is slightly in excess of this value. Thus all of the available steam can be used and only 20% or 205440 x .20% = 41088# steam can be charged against the Ball engines per

day for exhaust steam can be used in ice plant, laundry, etc. The water charges for these engines will be (41088÷ 1000÷ 625) x $52\frac{1}{2}$¢ (per 1000 cu. ft.) will bamount to $.345 per day, or $125.80 per year. The water cost against the rest of the plant will be (280,000÷ 1000÷ 625) x .525, and will amount to $2.37 per day, or $855.00 per year, making a total yearly water bill of $980.80.

Coal, which will evaporate seven pounds of water per pound of coal, will be considered. It is necessary to evaporate 280,000 x 365 plant, and 41080 x 365 = 15,000,000 lbs. of water for the engines. This represents 115,000,000 ÷ (7 x 2000) = 1072 tons for the engines and 7300 t. for plant. With coal at $2.90 per ton, the hotel coal bill per year will be 7300 x 2.90 = $21150 and the engine bill, 1072 x 2.90 = $3105.00 per year, or a total of $24200.00. Coal having 7% ash is considered. Thus there will be 7300 x .07 = 511 tons of ash from the hotel plant and 1072 x .07 = 75.04 tons of ash from the engine section of plant, per year. Handling these ashes through the Illinois tunnel at $2.00 per car of 3 1/2 cubic yards capacity, the cost will be (511 x 2.2 x $2) ÷ 3.5 = $646.00 against hotel and (75.04 x 2.2 x $2.00) ÷ 3.5 = $95.10 against the electrical plant. This amounts to $741.00 for ash handling per

year for the power plant.

The cost for the oil necessary to run the entire plant for one month may be taken as 50 gallons of cylinder oil- at .33 = $16.50 and 50 gallons of engine oil at .18 = 9.00, or a total of $25.50 per month. Of this amount, twenty gallons of each oil can be charged against the engines and generators, or $10.20 per month. This totals $305.00 per year for the plant, and $122.40 per year against the engine.

About 60 lbs. of waste will carry the plant for one month and about 25 lbs. of this can be charged against the engines. With waste at $.095 per lb. the waste bill per year for the entire plant is 60 x .095 x 12 = $69.50, and 25 x .095 x 12 = $28.60 for the engines. Packings can be set down at $50.00 per year for the entire plant, and $25.00 against the engines. Boiler compound will cost about $150.00 per year or about $38.00 for the extra boiler necessary for the engines.

The electrical energy consumed by the conveyor motor will amount to about 5 kilowatts x 1 1/2 hrs. per day x 365 = 2730 hours for the handling of 8372 tons of coal. With energy at .02 per kilowatt this amounts to $54.60 per year, of which $8.72 must be charged against the engines. for [illegible].

The cost of lighting the plant will amount to 80 lamps x 40 watts + 1000 x 24 hrs. x 365 x $.02 per

kilowatt = $561.00 per year.

To run the plant would require one fireman, one engineer, one assistant engineer to be present at all times, also one head engineer throughout the day (8 hours), one fireman's helper throughout the day (12 hours).

3 Firemen (8 hrs.at 30¢)	$216.00	per mo.
1 Engineer	110.00	"
3 " (at $90 per mo)	270.00	"
3 Engineer's helpers(at $60 per mo.)	180.00	"
1 Fireman's helper	50.00	"
Supervision	250.00	"
	$1076.00	"

Even without the engines all of the above men are necessary, with, perhaps, the exception of two engineers' helpers at $60.00 per month. Then $1440.00 per year must only be charged against the engines and generators. The total plant, yearly labor and supervision cost will total to $11472.00.

Cost of Power Plant

Fixed Charges.

4 - 300 H.P. Sterling Boilers	21,000.00
4 - Green Chain Grates, 2 4HP Engines	4,400.00
2 - Feed Pumps, Canton Hughes Co.	1,500.00
Other Canton Hughes Pumps	3,700.00
Steam Pumps, American Pump Co.	1,715.00
Yeoman Pumps	2,700.00

1-Feed Water Heater	$1500.00
Coal Conveyor,etc.Link Belt Co.	4000.00
3-Generators Crocker Wheeler Co.	11000.00
3-Engines. Ball Engine Co.	17000.00
Foundations for generators and engines	3400.00
Steam piping	9000.00
1-Switchboard and connections,Kohler Bros.Co.	9123.00
4-Coal Bunkers	6000.00
1-Ash bunker	1500.00
1-Chimney	7000.00
Breeching	500.00
	$105,038.00

Interest	5%
Depreciation	6%
Insurance,Real Estate,etc	3%
	14%

$105038.00 x 14% = $14705.32 yearly cost against plant.

Oil	305.00
Water	980.00
Coal	24200.00
Ash	721.00
Waste	69.50
Packing	50.00

[illegible]

[illegible]

[illegible]

[illegible] = [illegible]

[illegible]

Boiler compound	150.00
Lighting plant for 1 year at $.02 per K.W.hr	561.00
Power used in conveyor per year at $.02 per KWhr	54.00
	$27091.10
Labor and Supervision	11472.00
	$38563.10
Fixed charges per year	14705.00
	$53268.10

Number of thousand pounds of water evaporated per year is equal to (321088 x 365) ÷ 1000 = 117097 thousand pounds.

Thus

The cost of production of one thousand pounds is 53268 ÷ 117097 = $.454.

Cost of Generating Electrical Emergy.

Fixed Charge.

1 - 300 HP boiler	5250.00
1- Grate	1100.00
Additional size feed water heater	540.00
" " conveyor	800.00
" piping	3000.00
Generator panels and connections	4500.00
1-Coal Bunker	1500.00
Additional size chimney, Breeching	1500.00
3-Generators	11000.00

3-Engines	17000.00
Foundations for engines and generators	3400.00
	49590.00

Fixed charges per year.

Interest, Depreciation, Insurance, Real Estate at 14%.

49590 x .14 = $6942.60

Yearly charges.

Water	125.80
Coal	3105.00
Ash	95.10
Waste	28.60
Packing	25.00
Boiler compound	38.00
Power used in conveyor per year at $.02 per KW hr.	8.72
Oil	122.40
	$3548.62
Labor	1440.00
Fixed Charges	6942.60
	$11231.22

Total yearly KW consumption is equal to

214 x 24 x 365 = 1894640 kilowatt hours.

$11931.22 ÷ 1894640 = .637 cents is the cost per K.W.

The Sherman Hotel comes under Schedule "C" of the Commonwealth Edison rates, which reads as follows:

Primary Charges:

20 kilowatts of maximum demand in a month at $3.20 per kilowatt.

30 kilowatts of maximum " " " " " 2.50 per kilowatt.

Remaining kilowatts of maximum demand in a month at $2.20 per kilowatt.

Secondary Charges:

2000 kilowatts at $.06 per kilowatt hour
3000 " " .03 " " "
25000 " " .0125 " " "
70000 " " .012 " " "
Remaining " " .010 " " "

Applying this schedule to the load as obtained from the curve, the cost per kilowatt hour is $.01762.

Primary Charge:

20 kilowatts at $3.20 = $64.00
30 " " 2.50 = 75.00
300 " " 2.20 = 660.00
$799.00

Secondary Charge:

2000 kilowatts at $.06 = 120.00
3000 " at .03 = 90.00
25000 " at .0125 = 312.50
70000 " at .012 = 840.00

Forward ----------------	1362.50
54080 kilowatts at .01 =	540.80
154080 "	=$1903.30
Primary Charge	799.00
Total Monthly bill---	$2702.30

Total monthly consumption 154080 kilowatt hours.

Cost per kilowatt is 2702.30 ÷ 154080 = $.01762/kilowatt hour.

As the cost of generating electrical energy in the plant designed was only .632 ¢ per kilowatt hour the saving is 1.125¢ per kilowatt hour consumed.

The yearly saving is

0.01125 x 154080 x 12 = $20800.80

Throughout the above work the aim has been to give figures and conditions as close as possible to the actual ones, and no doubt a close study of the same will disclose these facts. This large saving is indeed hard to believe at first sight, but it is believed by the writers to be very close to the actual saving that would be made if an electrical plant were installed in connection with the present steam plant at the Hotel Sherman. It can be explained by the fact that the total exhaust for the engines is available the year around, due to large steam consumption of the Hotel kitchen and laundry. The above saving would pay for the electrical plant in two and one fourth years.

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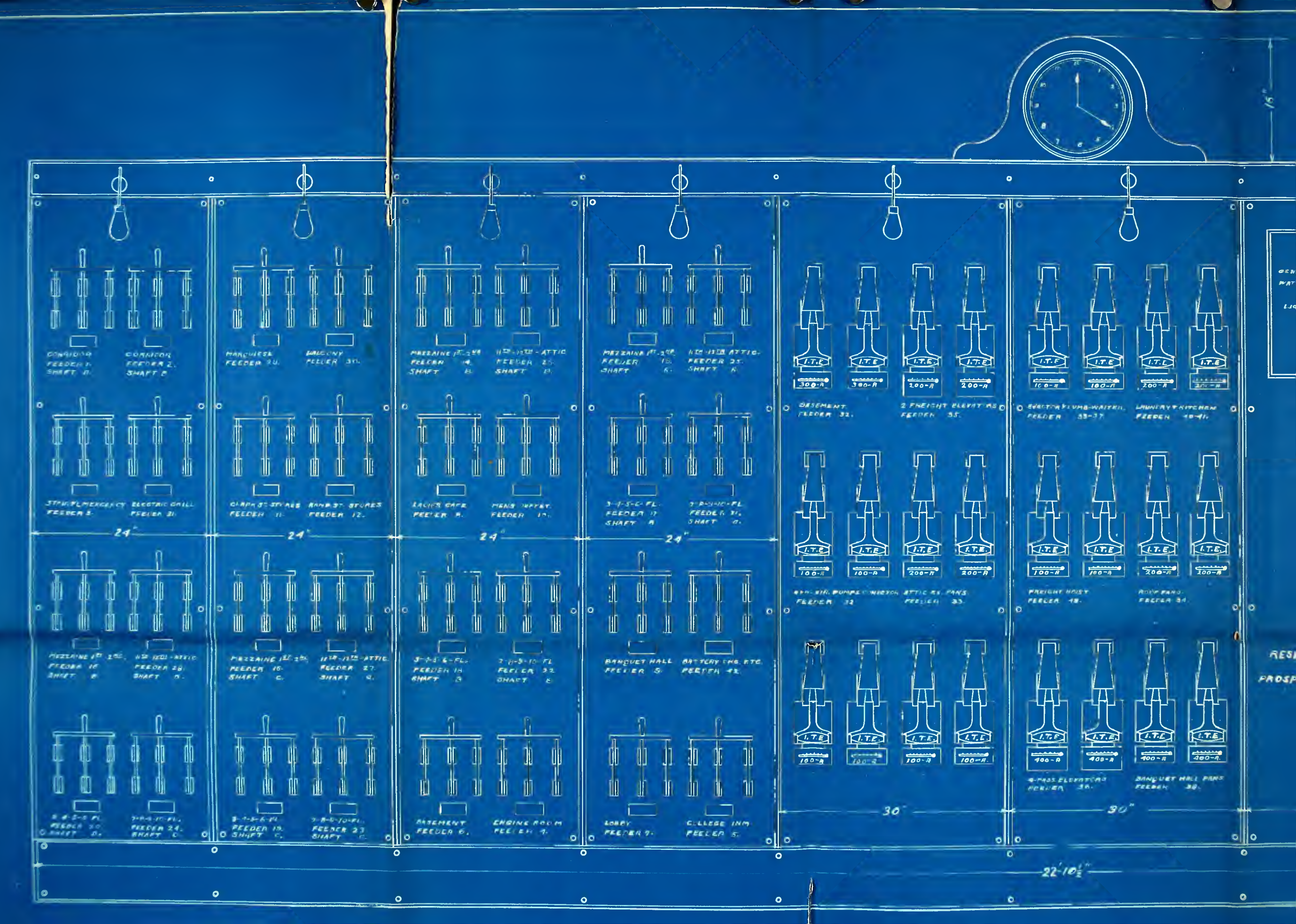
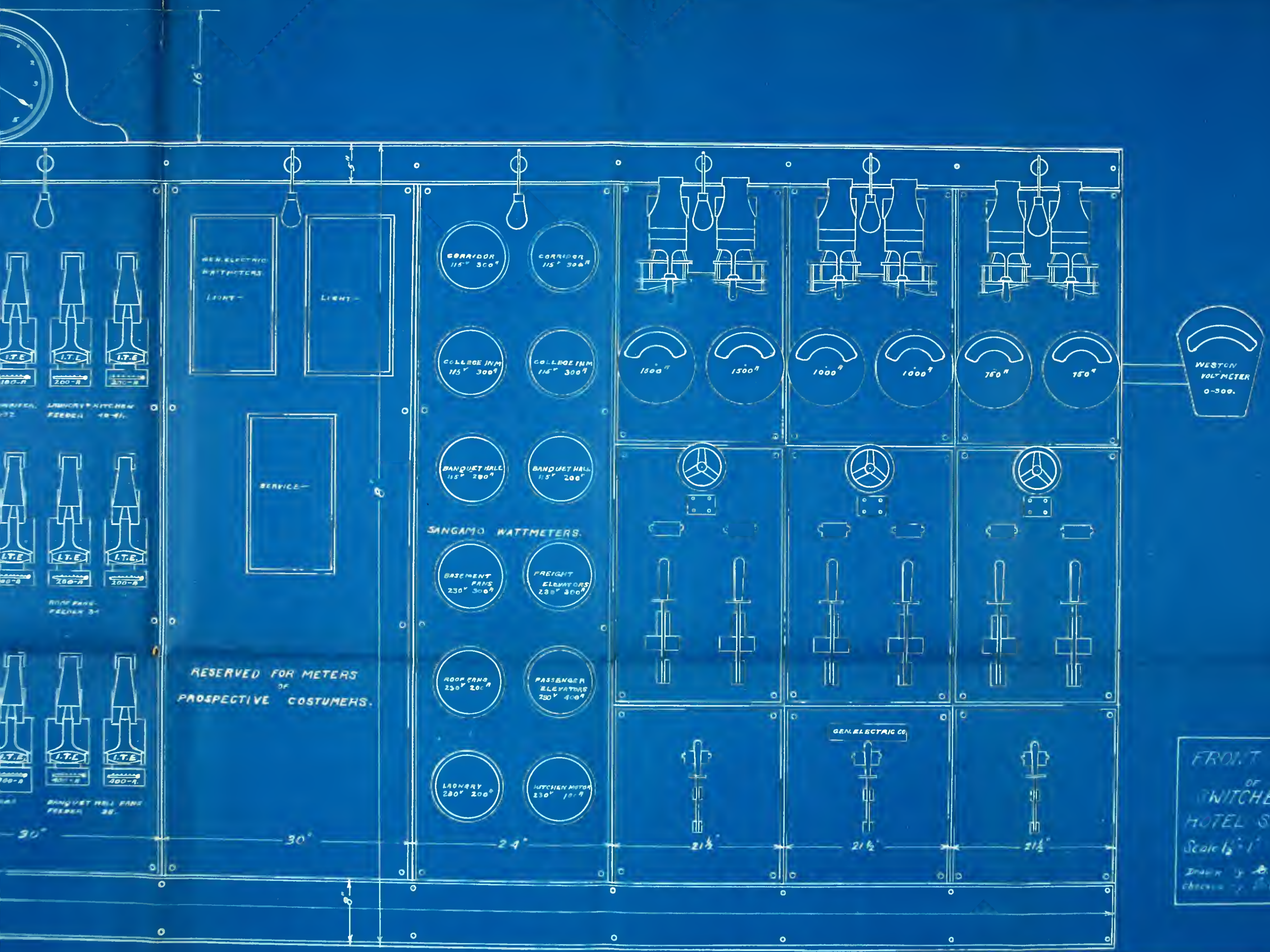
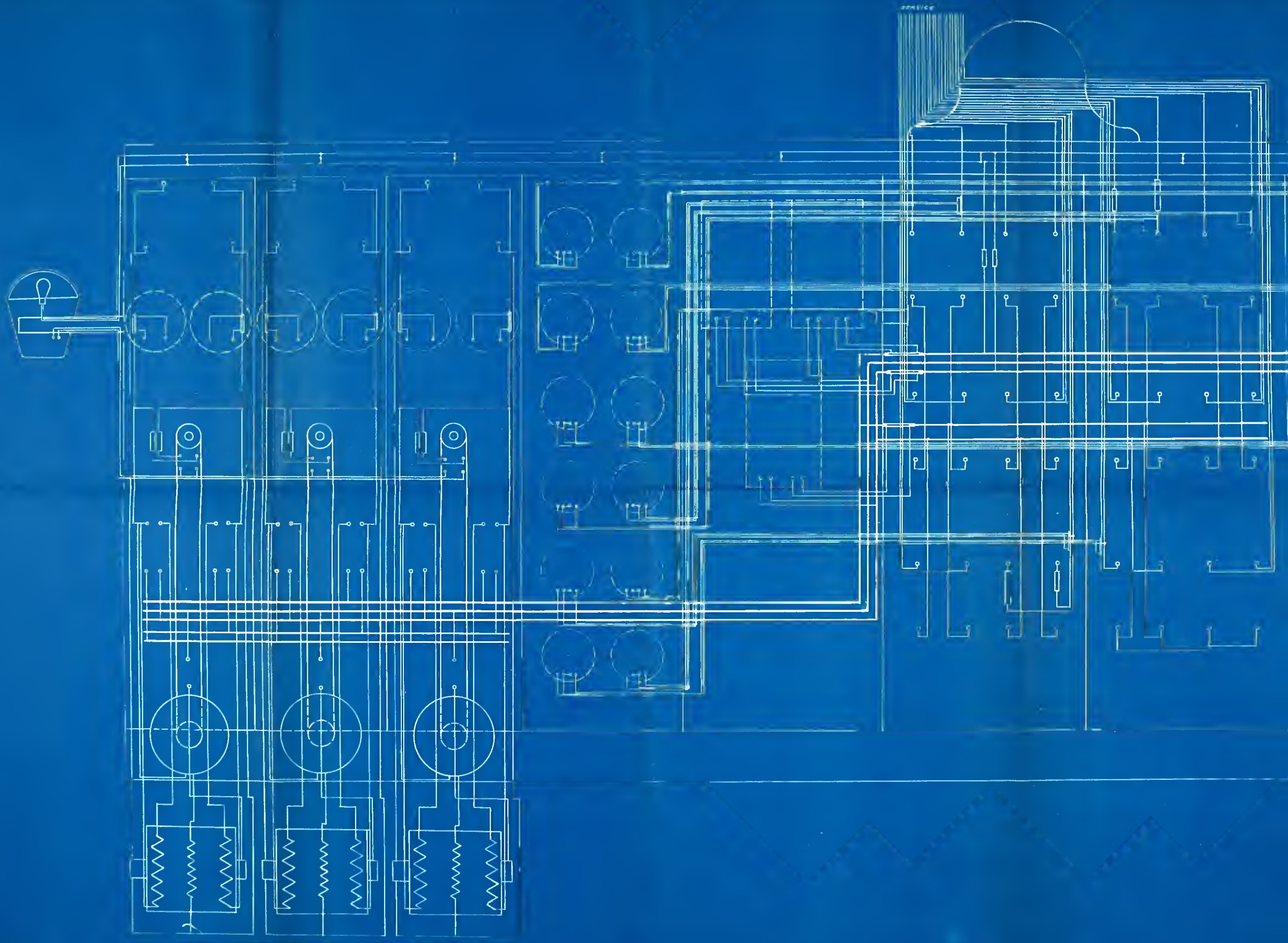
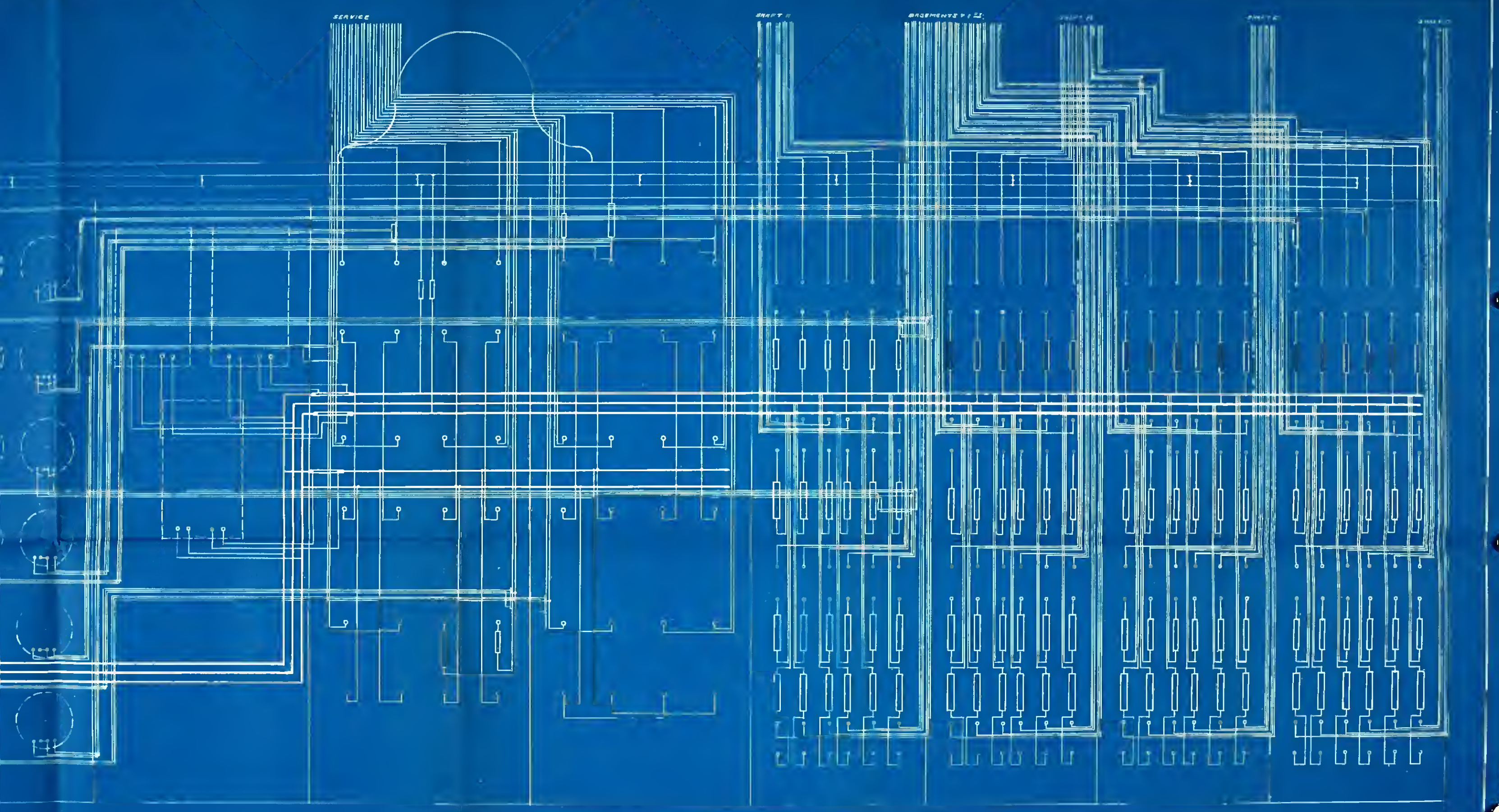

16"
CORRIDOR FEEDER 1. SHAFT A.
CORRIDOR FEEDER 2. SHAFT B.
MARQUESE FEEDER 29.
BALCONY FEEDER 30.
MEZZAINE 1ST-2ND FEEDER 14. SHAFT B.
11TH-12TH-ATTIC FEEDER 25. SHAFT B.
MEZZAINE 1ST-2ND FEEDER 13. SHAFT K.
11TH-12TH ATTIC. FEEDER 25. SHAFT K.
STR'G. FL. MERGENCY FEEDER 3.
ELECTRIC GRILL FEEDER 31.
CLARK ST. STORES FEEDER 11.
RAND. ST. STORES FEEDER 12.
LADIES CAFE FEEDER 8.
MENS BUFFET FEEDER 10.
3-4-5-6-FL. FEEDER 17 SHAFT A
7-8-9-10-FL. FEEDER 21. SHAFT A.
24"
24"
24"
24"
MEZZAINE 1ST 2ND. FEEDER 16 SHAFT D.
11TH 12TH-ATTIC FEEDER 28. SHAFT D.
MEZZAINE 1ST 2ND. FEEDER 15. SHAFT C.
11TH-12TH-ATTIC. FEEDER 27. SHAFT C.
3-4-5-6-FL. FEEDER 18 SHAFT B
7-8-9-10-FL. FEEDER 22. SHAFT B
BANQUET HALL FEEDER 5.
BATTERY CHG. ETC. FEEDER 42.
3-4-5-6-FL. FEEDER 20. SHAFT D.
7-8-9-10-FL. FEEDER 24. SHAFT D.
3-4-5-6-FL. FEEDER 19. SHAFT C.
7-8-9-10-FL. FEEDER 23 SHAFT C.
BASEMENT FEEDER 6.
ENGINE ROOM FEEDER 4.
LOBBY FEEDER 7.
COLLEGE INN FEEDER 5.
I.T.E.
300-A
300-A
200-A
200-A
100-A
100-A
200-A
200-A
BASEMENT FEEDER 32.
2 FREIGHT ELEVATORS FEEDER 35.
EJECTOR & DUMB-WAITER. FEEDER 33-37.
LAUNDRY & KITCHEN FEEDER 40-41.
100-A
100-A
200-A
200-A
100-A
100-A
200-A
200-A
BSM. SUMPS & EJECTOR FEEDER 32
ATTIC EX. FANS FEEDER 33.
FREIGHT HOIST FEEDER 48.
ROOF FANS FEEDER 34.
100-A
100-A
100-A
100-A
400-A
400-A
400-A
400-A
4-PASS. ELEVATORS FEEDER 36.
BANQUET HALL FANS FEEDER 39.
30"
30"
22'-10½"
GEN
WAT
LIG
RES
PROSP

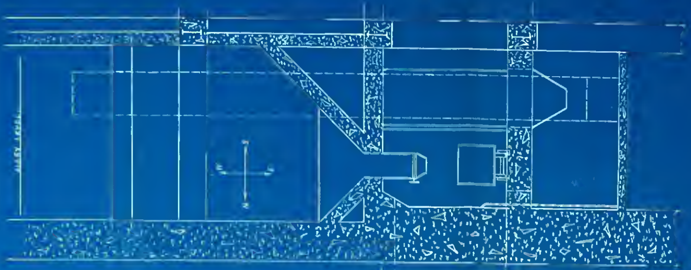


FRONT VIEW
OF
SWITCHBOARD
HOTEL SHERMAN
Scale 1½" = 1' April 29 '12
Drawn by [illegible]
Checked by [illegible] Meade

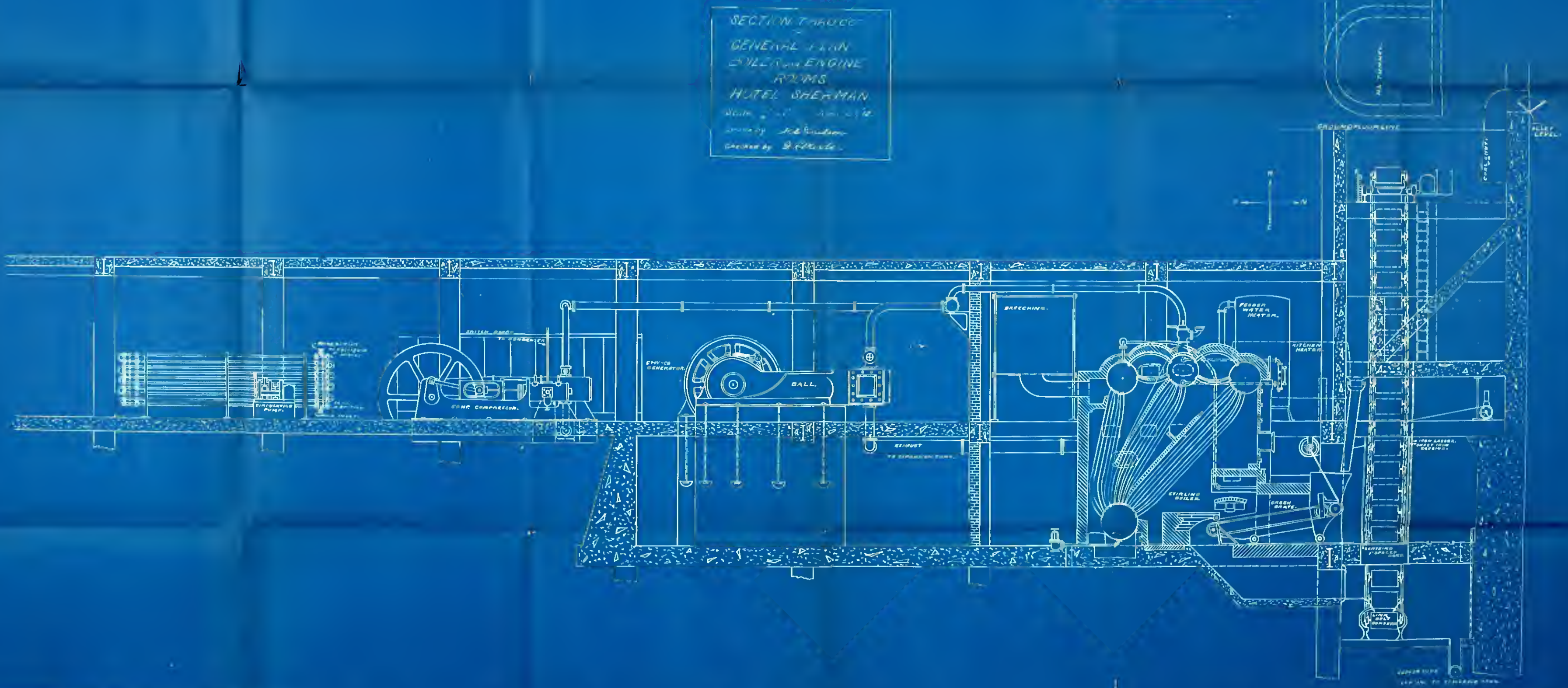

SERVICE



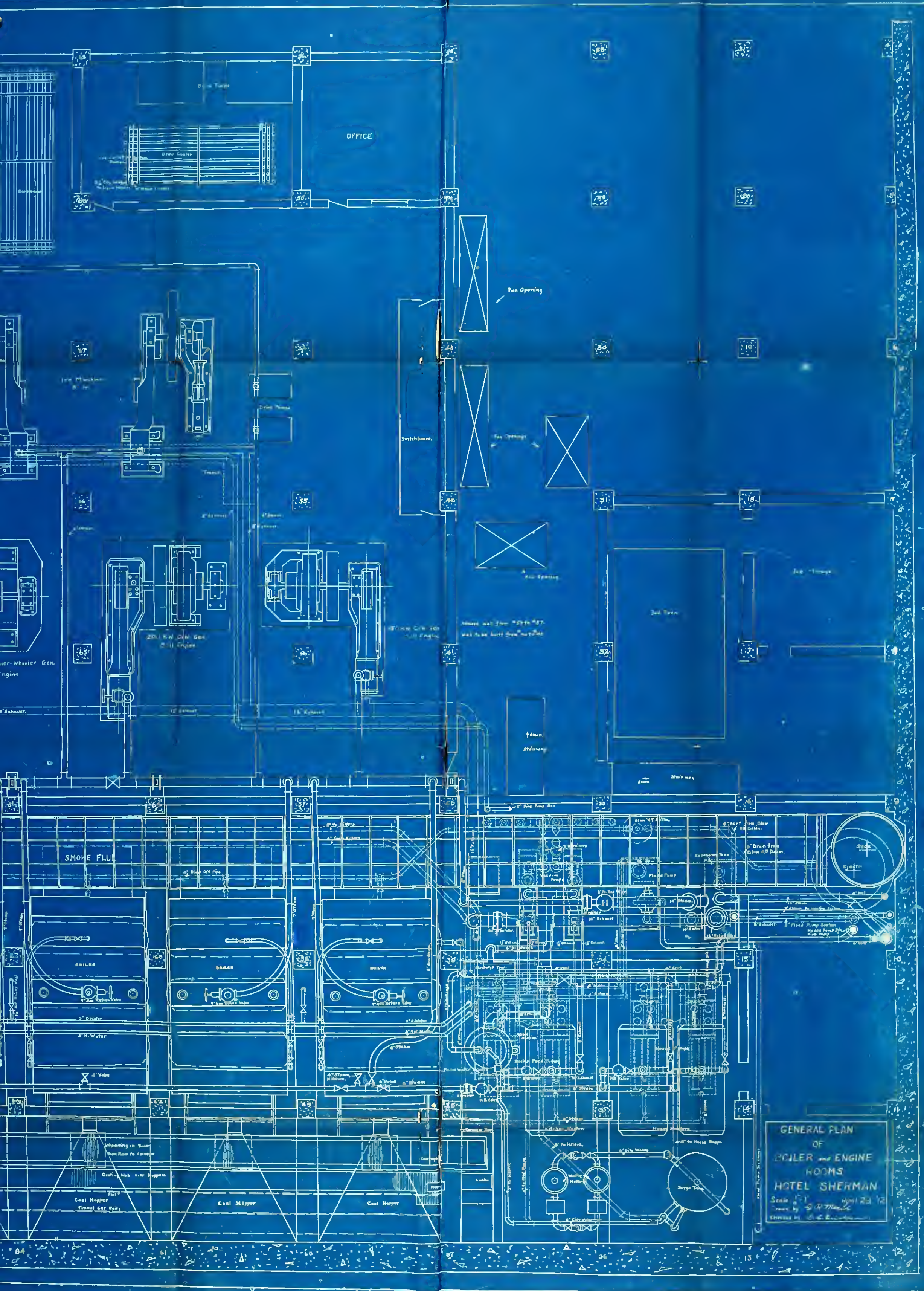
SWITCHBOARD
WIRING DIAGRAM
HOTEL SHERMAN
Scale 1½" = 1' April 29 '12
Drawn by [illegible]
Checked by [illegible]



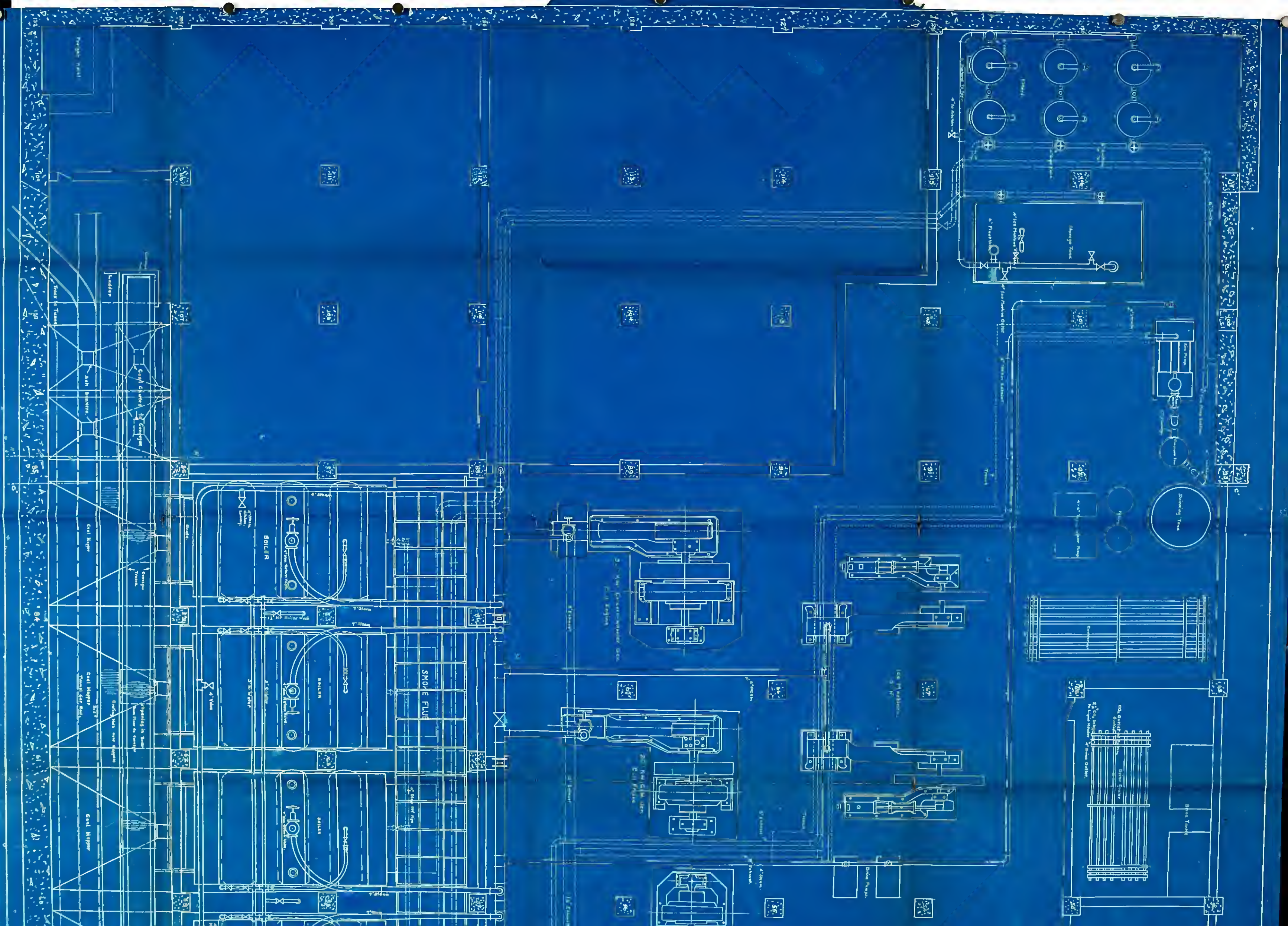
SECTION THRU AA′
OF
GENERAL PLAN
Scale ¼″ = 1′



SECTION THROUGH
OF
GENERAL PLAN
BOILER and ENGINE
ROOMS
HOTEL SHERMAN
Scale
Drawn by
Checked by



GENERAL PLAN
OF
BOILER and ENGINE
ROOMS
HOTEL SHERMAN
Scale $\frac{1}{8}$"=1'   April 23 '12
Drawn by S. A. Marsh
Checked by C. E. Burroughs


Track to Tunnel
Ladder
Ash Bunkers
Coal Chutes to Conveyor
Coal Hopper
Conveyor Tracks
Grate
BOILER
BOILER
BOILER
3" Water
6" Steam
7" Steam
7" Steam
7" Steam
1½" HP Boiler Wash
4" Valve
Coal Hopper
Tunnel Car Rail
Grating Walk over Hoppers
Opening in Boiler Room Floor to Conveyor
Coal Hopper
SMOKE FLUE
4" Blow off Pipe
Engine
Exhaust
6" Steam
Exhaust
Brine Pumps
Ice Machine
Condenser
Filters
4" to Kitchen
Storage Tank
4" Ice Machine
6" Flood Valve
4" Ice Machine Outlet
Fire Pump
Drinking Tank
CO₂ Outlet
Brine Outlet
Brine Cooler
Brine Tanks
85
84
108
109
107
116
117
118
95
55
56